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ABSTRACT

An experimental course in introductory organic chemistry at the University of Texas at Austin made use of the computer for drill and routine instruction. Lecturing time was reduced, and computer lessons were made part of the required coursework. This experimental situation was planned on the basis of results from previous experiments using computer-assisted instruction (CAI) in chemistry courses. Evaluation of student performance showed equivalence or improvement using the experimental approach compared to the traditional course. Student attitude surveys revealed support for the individual, self-paced, tutorial approach. Perceived disadvantages included time needed to complete computer-based lessons and difficulties with the computer system hardware. (CH)

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ADAPTING COMPUTER-BASED INSTRUCTION TO UNDERGRADUATE ORGANIC CHEMISTRY: AN EXPERIMENTAL COURSE

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INTRODUCTION

The feasibility of using computer-based instructional techniques in undergraduate organic chemistry has been documented and described previously.[1-6] The earlier studies at The University of Texas at Austin using programs developed by Dr. G. H. Culp, with the cooperation of Professors L. B. Rodewald, P. L. Stotter, and J. C. Gilbert, were conducted under experimental conditions in which randomly selected groups were given access to computer-based lessons and compared in terms of performance and attitudes with a control group from the same class. In each case the groups were relatively small in number, and with the exception of access to supplemental computer-based lessons, the course was conducted in the traditional method of three 50-minute lectures and one 4-hour laboratory per week. We present here a description of the first attempt in which the conventional organic course has been modified as a result of these earlier studies to include computer-based instructional techniques within the curriculum.

COURSE DESIGN

A first semester course in introductory organic chemistry designed for chemistry and chemical engineering majors was designated as the experimental course. The text used was "Organic Chemistry" by Morrison and Boyd (2nd Edition). One hundred six students were originally enrolled in the course; 73 students completed the semester.

The design of the experimental course differed from that of the traditional course described above in several respects. The number of lecture sessions was decreased from three to two 50-minute meetings per week. The time normally reserved for the third formal lecture was available as an optional discussion period. Twenty-one computer-based lessons (see Table I) were assigned as a required part of the course.[1] The lessons were written in CLIC (Conversational Language for Instruction and Computing), an interactive computer language developed by personnel of the University of Texas Computation Center, and designed for the University of Texas CDC-6600/6400 system. A minimum level of achievement of 85 percent was established for most of the lessons. If this level was not attained, the student did not receive credit for the lesson. The regularly assigned laboratory periods were not modified.

A priori, this modified course design was predicated on the now-documented rationale for using computer-based instructional techniques,

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1. A brief abstract including performance objectives for each lesson is available from the authors.

i.e., there are certain aspects within the learning process that may be treated more effectively by computer-based tutorial interactions, with the potential of providing self-paced, individualized instruction, than by classroom structured human interactions. In this regard, the computer lessons emphasized areas that require drill--often patient, tutorial drill--and simulated experiment or reaction applications in which the student may control several experimental parameters without the constraints of available time, equipment and space. Furthermore, this design allowed the instructor to be freed from much of the routine instruction inherent within the traditional approach, and the two weekly lectures were devoted almost entirely to more generalized theoretical concepts of bonding, structure, stereochemistry, and reaction mechanism.

Three hour exams totaling 500 points and a final exam totaling 650 points were given. Points were also assigned to the semester laboratory grade (A = 400 to D = 100) and 150 points were credited to students who had successfully completed at least 20 of the computer lessons. Ten points were deducted for each lesson not completed. The course grade was contingent upon the total number of points attained.

EVALUATION

The background abilities as measured by SAT mathematics and verbal scores, and the semester performance of the experimental class, were compared with a more traditional class taught by the same instructor 18

months earlier. These grade distributions were also compared with two traditional courses taught by different instructors during the same periods. In addition, attitudes and opinions were formally solicited from students in the experimental class.

RESULTS AND DISCUSSION

Student Performance. The distribution of course grades and other pertinent data for the four classes are shown in Table II. In terms of achievement, the data suggest, not only equivalence of background ability for the two classes with the same instructor, (X), but also that the experimental approach is on a level equal to or better than the traditional approach. In this comparison, improvement is indicated in the middle and lower achievement groups for the experimental class, supporting the findings of the earlier studies in organic chemistry that show these groups can most benefit from the individualized, tutorial-drill instruction provided by the computer-based lessons. Comparison of the experimental class with the two traditional classes taught by different instructors indicates no significant differences in the distribution of passing grades. It is interesting, however, to note the small percentage of failing grades and the relatively high percentage of drops without penalty for the experimental course. These percentages suggest that in the experimental course each student is better able to determine early in the semester whether he would devote sufficient time to complete the course successfully and, if not, drop without penalty while his work is still at a satisfactory level.

Three of the computer lessons were directly related to the laboratory portion of the course: one to gathering, interpreting and reporting laboratory results; and two to simulated experiments prior to related, real experiments in the laboratory. A general improvement is shown in Table III in laboratory performance for the experimental class. Considering that the laboratory grade is based primarily upon laboratory reports of real experiments and performance on quizzes related to technique and/or theory, the distribution again suggests that the experimental course design is, at the least, the equivalent of traditional instruction.

Student Attitudes. Student opinion regarding the design of the course and specifically the use of computer-based techniques is shown in Table IV. Positive attitudes are given by a majority of the students on four of five items, particularly those relating to assistance in learning provided by the computer lessons. The one negative response related to the equivalency of time required for one-lecture vs. one-lesson is a legitimate response supported by the actual computed time required to complete a lesson successfully. (See Time Required below) However, the longer time period to complete a lesson is probably a function of the minimum achievement level defined for each lesson, and the fact that many students came unprepared to their first interaction with each lesson.

Students indicated a preference for the areas of nomenclature, simple reactions, synthesis and spectral interpretation as being well-suited for computer-based lessons.

Advantages listed were overwhelmingly in support of the individual, self-paced, tutorial approach given by the computer lessons, along with the active participation of the student. In this regard, the instructor noted an unusual level of positive excitement and anticipation among the students throughout much of the semester.

Disadvantages listed included the time required to complete the computer-based lessons successfully, certain idiosyncrasies within individual lessons that failed to recognize an acceptable correct response, and problems with the computer system hardware that necessitated the postponement of scheduled interactions with the lessons.

Time Required. Table V contains data concerning the time required and cost figures for the semester. A total of 2,082 jobs requiring 1,490 computer contact hours for the students occurred in the semester. On the average, about 1.6 interactions were required per lesson per student for a successful completion. This is the equivalent of about 43 minutes per job, and, assuming that one job represents one lesson, about 70 minutes for a successfully completed lesson.

Costs. Computer costs are based upon a rate of $260.00 per TM hour (a combination of central processing (CP) and peripheral processing (PP) time) and a line connect charge that was originally $0.50 per hour but was reduced in the 10th week of the semester to $0.40 per hour. A total of 7.21 TM hours costing $1875.10 and $667.65 for connect time were required for the 2,082 jobs. This is approximately $1.71 per student terminal hour or $1.99 total

cost per successfully completed lesson per student. It is very important to note, however, that a rate of only $26.00 per TM hour is charged at the departmental level within the University system. Had funds for this project come directly from the Chemistry Department teaching budget (rather than a research account), the cost would have been about $0.58 per student terminal hour.

SUMMARY

An experimental course in first semester undergraduate organic chemistry was designed to incorporate documented computer-based instructional techniques. The design included required computer-based lessons that provided tutorial drill and practice and simulated experiment and reaction applications. Most of the lessons required a minimum achievement level of 85 percent for credit. Since much of the routine instruction was accomplished within the computer lessons, it was possible to reduce the number of formal lectures per week from three to two, but simulataneously to increase the amount of time and detail devoted to theoretical concepts such as bonding, structure, stereochemistry and reaction mechanism.

Evaluation of the experimental course by comparison with 3 courses taught by traditional methods, including one taught by the instructor of the experimental course, indicated the experimental course to be on a level equal to or better than traditional methods. Positive student attitudes and opinions for the experimental course were also received.

On the average, successful completion of a computer lesson required about 70 minutes and cost $1.99 per student.

REFERENCES

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4. Culp, G. H., and Lagowski, J. J., J. Res. Sci. Teach., 8: 357, 1971.
5. Smith, S. G., Journal of Chemical Education, 48: 727, 1971.
6. Venier, C. G., and Reinecke, M. G., Journal of Chemical Education, 49: 541, 1972.

TABLE I

ASSIGNED COMPUTER LESSONS

	Name	Area
1.	OCH16	Valence Bonding and Organic Compounds
2.	OCH34	Classes of Organic Compounds
3.	OCH1	Alkane Nomenclature
4.	OCH22	Separation via Extraction
5.	OCH18	Chlorination of Propane
6.	OCH24	Basics of Stereochemistry
7.	OCH2	Alkene Nomenclature
8.	OCH14	Dehydration of 2-Methylcyclohexanol
9.	OCH10	Preparations and Reactions of Alkenes
10.	OCH31	Reporting Laboratory Results
11.	OCH17	Elementary Alkene-related Syntheses
12.	OCH4	Arene Nomenclature
13.	OCH19	Mechanism of Electrophilic Aromatic Substitution; Orientation; Reactivity
14.	OCH11	Preparations and Reactions of Arenes
15.	OCH6	Elementary Aromatic Syntheses
16.	OCH7	Aromatic Syntheses
17.	OCH3	Alcohol, Aldehyde, Ketone Nomenclature
18.	OCH12	Preparations and Reactions of Alcohols
19.	OCH29	Preparations and Reactions of Phenols
20.	OCH32	Elementary NMR Interpretations
21.	OCH33	Elementary IR Interpretations

TABLE II

SEMESTER GRADE DISTRIBUTION

Year	Instructor	Grades (%)								SAT	SAT
		A	B	C	D	F	F[a] (abs)	Q[b]	X[c]	(Verbal)	(Math)
72[d]	X	10	16	22	16	4	2	27	3	549	629
70	X	12	13	16	20	9	0	20	20	558	639
72	Y	9	22	20	15	13	0	20	0	-	-
70	Z	7	17	22	12	16	13	14	0	-	-

[a]Absent from class, but failed to drop the course officially

[b]Dropped the course without penalty

[c]Incomplete grade assigned

[d]Experimental course

TABLE III

LABORATORY GRADE DISTRIBUTION*

Year	Instructor	Grades (%)				
		A	B	C	D	F
72**	X	35	44	21	0	0
70	X	23	40	29	8	0
72	Y	29	35	29	7	0
70	Z	22	34	42	1	1

*For students completing the course

**Experimental course

TABLE IV

STUDENT ATTITUDES

Item	Opinion (%)				
	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1. Computer techniques are good study aids	3	3	2	54	37
2. The time required for these lessons was the equivalent of the traditional 3rd formal lecture	17	44	12	23	3
3. The lessons have helped me learn	3	2	9	53	33
4. I have enjoyed the lessons	11	5	22	36	26
5. I would use this type of study aid in other courses if it were available	7	5	28	40	19

TABLE V

TIME REQUIRED AND COST OF INTERACTIONS

Number of jobs (sign-ons) run:	2,082
Hours of computer connect time:	1,489.89
Computer TM* hours:	7.21
Computer TM charge:	$1,875.10
Computer connect time charge:	$667.65
Hours per successfully completed module:	1.17 (70 minutes)
Cost per successfully completed module:	$1.99
Cost per student-terminal hour:	$1.71

*TM hour includes central processing time and peripheral processing time.